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MEMORANDUM FOR: Deputy Director for Science and Technology

SUBJECT: Interdiction of Mu Gia and Neighboring Passes to the Flow of Personnel and Materiel

REFERENCES:

a. The Role of Airstrikes in Attaining US Objectives in North Vietnam, CIA - [redacted] March 1966, Top Secret 25X1

b. Potential Chokepoint in Mu Gia Pass Area, North Vietnam, CIA/BI GB66-21, February 1966, Secret

INTRODUCTION

Statement of the Problem:

VC and North Vietnam Forces in South Vietnam and Laos are being principally supplied through the Mu Gia Pass. The feasibility of denying the use of this and neighboring passes for the transport of these supplies by means of aeriel laid bombs and mines is desired, forcing the portage of the materiel over the surrounding mountainous area or the use of alternate routes. A current estimate of 70-90 tons per day for the present traffic, and a projected requirement of approximately 200 tons per day under an escalated scale of combat, establish a rough measure of the level of transport for the purposes of this study.

Scope:

The report proper considers the background of the problem, the geographical particulars, the measures of effectiveness used, and the study results. The detailed consideration of the weapons and the models used in the analysis, together with trade-off considerations, is given in a Technical Annex.

Currently available, developmental, planned, and conceptual munitions are considered in this study in successively less detail. The state-of-the-art is reasonable mature and reasonably reliable projections may be made in most of the areas.



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The requirements imposed upon the delivery systems by weather are included in the analysis. This problem is closely related to the scheduling of the munitions over the target and thelife of the implanted devices.

This study does not consider the larger problem as to the value of the interdiction of these passes as this issue is considered in a separate, larger study, Reference a. The installation of an air defense system at the passes is a possible counter to this interdiction and one that would significantly increase the estimated weapon's delivery costs through attrition of the delivery aircraft, although this part of the problem is not considered in this report. This report considers the logistics of the weapons delivery only generally, assuring that the solutions proposed are reasonably compatible with existing aircraft. No effort has been made to minimize the delivery cost by a detailed consideration of weapons/aircraft compatibility, operating costs and aircraft availability and attrition.

The study is considered to define the feasibility of the proposed task in terms of the costs to either side to achieve specific objectives. Approaches to the solution are identified which would require further definition prior to implementation.

## SUMMARY AND CONCLUSIONS

<u>Summary:</u>

The road network in the neighborhood of the Mu Gia Pass was examined for alternate routes. Three additional routes appeared to be significant: the Kea Neua Pass which joins Route 8, a pass near the Demarcation Line carrying Route 102 (Veng Khuch), and a third area south of the Mu Gia Pass where a road is being constructed. This last road is not complete, and complete information on the path that the road will take is not available. The Mu Gia, the Kea Neua and the Veng Khuch Passes were therefore assumed to define the required interdiction problem.

Photographs of the area showed the ground cover was not extremely dense, and that the road is single lane, but probably has shoulders for passing. The steep side of the

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Mu Gia Pass is subject to slides, and road building would therefore be very difficult there. The general area is rugged, and, except for the Mu Gia Pass, there were few obvious terrain features which might logically define an interdicted area. The areas selected are shown in Figures 6, 7 and 8.

The measures of effectiveness used in evaluating the performance of bombs and ordnance in denying the selected areas to transversal by personnel was taken to be the munitions cost for all three passes required to provide both:

a. An unacceptable level of casualties for transversal of the area without sweeping.

b. A sufficient number of mines or decoys in the path so that the length of time required to breach the field was equal to the replenishment rate.

The measure for road interdiction was taken to be the cost of damaging the road and preventing its maintenance or a 24 hour/day basis i.e., 100% closure of the road, in three places in each pass.

A review of all the available, planned, and projected ordnance of knowledge to the Air Force Armaments Laboratory at Eglin Field was made to select those device with the best promise for strategic interdiction. For the denial of the areas selected, the Dragontooth appeared to be best of the "available" devices, but the Trip Wire Mine, supplemented by decoys hypothecated for the purposes of the study is markedly superior for area denial.

The problem of interdicting the roads appears to be possible if conventional high explosive devices are supplemented with Napalm B fire bombs and Trip Wire Mines to make repair of the roadway difficult and hazardous.

Findings:

The findings are sensitive to the assumptions used in this report and Technical Annex, and should be substantiated by a more detailed examination of the problem prior to any

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action to implement either the denial concepts or the initiate an R&D program in support of the conceptual devices described. This preliminary survey of the interdiction problem has resulted in the findings listed below:

a. No ordnance in the inventory is applicable to the area denial problem at a reasonable cost.

b. The Trip Wire Mine under development by the Air Force shows promise for area denial to troops or bearers walking through an area without cover. At an annual cost of $82,000,000 this mine will deny the areas shown in Figures 6, 7 and 8 such that the cost to penetrate each field without breaching is 20 casualties. The estimated length of time to breach the field without casualties is equal to the nominal 8 hour replenishment period. A trade-off exists between these extreme strategies, but the problem has not been considered in sufficient detail to describe the trade-off relationship.

c. The addition of trip wire decoys (assumed in Paragraph b above) and random time-delay in the deployment of the trip wires could greatly increase the difficulty and time to breach a field of trip wire mines. These changes will not significantly decrease the casualties expected when the field is penetrated without mine clearance for the same cost and payload.

d. A counter to the solutions b and c above is the construction of a covered trench through the area. This could be constructed for roughly 1500 to 2000 man days per mile in soft earth, and would provide almost complete protection against all small anti-personnel ordnance. Large bombs would also be ineffective against this enemy reaction to our denial program.

e. The problem of road interdiction is not feasible using conventional high-explosive weapons alone, including the use of time-delay or influence fuzes.

The damage inflicted is not commensurate with the cost of delivery, and repair can be exceptionally rapid.

f. A more promising approach to the road interdiction problem is the use of Napalm B delivered with A-1E's on a continuous basis on a small segment of the road coupled with road damage by conventional explosives. On the basis of available data, the three roads through the passes of concern could be interdicted in three points for an annual cost of $104 million. This result is uncertain in extremely wet conditions or heavy rain. The existence of the fire should markedly assist in the vectoring of the aircraft to the interdiction point.

g. Ruling out the use of BW-CW, nuclear, or exotic weapons, no conceptual solution to the area denial problem was found which was better than that postulated in c above.

h. Guidance systems exist with sufficient accuracy for the area denial problem. In principle, guidance systems (such as Loran, Shoran and map-matching techniques) exist which will permit the blind delivery of road interdiction weapons. The cost and feasibility of doing this is subject to question, since the most sophisticated devices are deployed only on the larger, more expensive SAC aircraft. It might be practical, however, to implement the proposed road interdiction scheme with relatively simple navigation means because of the ability of the aircraft to see the Napalm fire, even in poor weather, or by the use of beacons.

Conclusions:

Area denial is not practicable with currently available weapons. The analysis made in the study indicates only a marginal capability for the Trip Wire Mine when supplemented with decoys and possibly modified to deploy the trip wires with a random delay. This analysis, however, did not consider side effects such as the morale factor and the denial of the use of area not regularly cleared and swept. Everything considered, it is concluded that the Trip Wire Mine deployed with decoys with or without the random deployment of the trip wires would be more effective than indicated in the study, and that the areas selected could be denied for less than the annual cost of $82 million given.

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No solution to the road interdiction problem was found that did not require aircraft on target almost continuously. The method proposed includes a combination of GP bombs to damage the road and Napalm B to prevent repair at an annual cost of $104 million for three interdiction points in each of three areas. The proposed solution depends upon published lethal area values for Napalm B, although these figures are now considered to be high, especially in wet weather or rain.

The study shows incidentally the extremely high effectiveness of the Trip Wire Mine when used to deny the use of area, rather than simple transversal. A more effective means of interdicting the movement of supplies might be the denial of area at depots, barracks or staging areas, where the restriction of travel to well defined and cleared paths is not practicable.

A more detailed investigation of the use of decoys and random wire deployment for the Trip Wire Mine should be made, if this aspect of the problem has not already received consideration, as the study shows a marked increase in the resistance of the mine to sweeping if these features are employed.

The closure of the Mu Gia and neighboring passes to personnel and the interdiction of the road traffic is estimated to cost, in ordnance, between $100 and $150 million per year using ordnance which could be developed within 18 months to 2 years. This presumes that the breaching of the passes is of sufficient importance that a concerted effort will be made. Available ordnance is not well adapted to the denial of the areas considered to the transversal of personnel.

BACKGROUND

Figure 1 shows the road network in the Mu Gia Pass area. There are three major passes through the mountains, and it is these passes that are to be interdicted. Pertinent aspects of the problem of interdicting the Mu Gia and neighboring passes concern the detailed topography of the passes, the nature of the vegetation and cover, the width and characteristics of the road, and the existence of alternate routes. A description of the topography in the neighborhood of the Mu Gia Pass is given in Reference 2.

The northernmost pass shown in Figure 1, that carrying Route 8, is not likely to be used for an appreciable amount of traffic because of the quality of the Laotian route with which it joins. Between the Mu Gia Pass and that near the Demarcation Line is a relatively low area in which there is a road under construction. This area is of extremely uniform

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but rough terrain (Karst). The features are sufficiently uniform that there is scarely a logical basis for selecting an area for interdiction. Since the exact location of the road is not known and the terrain is not very different from the other areas, the cost of covering this route can be estimated by extrapolation from the other passes. The pass carrying Route 8, Kea Neua, the Mu Gia Pass and the Veng Khuch carrying Route 102 near the Demarcation Line will be considered to represent the requirement for purposes of this study.

Several photographs are described below which bear on the above aspects of the problem. Figure 2 is a photograph taken at low level at one end of the Mu Gia Pass showing a maintenance camp and a portion of Route 12/15. Several factors are evident from this photograph. The ground cover and vegetation are not extremely dense, nor such as to prevent reasonably expeditious searches for mines. The route is one lane, but with generous shoulders such that passing is possible. The route should be considered as two-lane for purposes of calculating the damage required for interdiction.

Figure 3 shows the steep side of Mu Gia Pass. The slides shown on the steeper slope (about $42^{o}$) indicate that road construction on that slope would be very difficult. The very rough terrain in the background indicates that the terrain there is extremely rugged, and that building roads in this area would also be extremely difficult. Figures 4 and 5 are other photographs cooroborating the above points.

An important factor to be considered in the analysis is that the amount of traffic in the pass is not static, but will depend upon the number of Communist troops in South Vietnam and the extent of their activity. The estimated increase, however, is sufficiently below the road capacity that it may all be passed if the road can be opened periodically. The continuous interdiction of the road is thus a requirement for the success of the program.

REQUIREMENTS FOR INTERDICTION

The denial of the use of the Mu Gia and neighboring passes to the flow of traffic requires the interdiction of the road proper and the denial of the surrounding area. Presently available or developmental ordnance does not exist which would be at all useful in such a multipurpose application.


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Figure 1. Location of Interdicted Passes

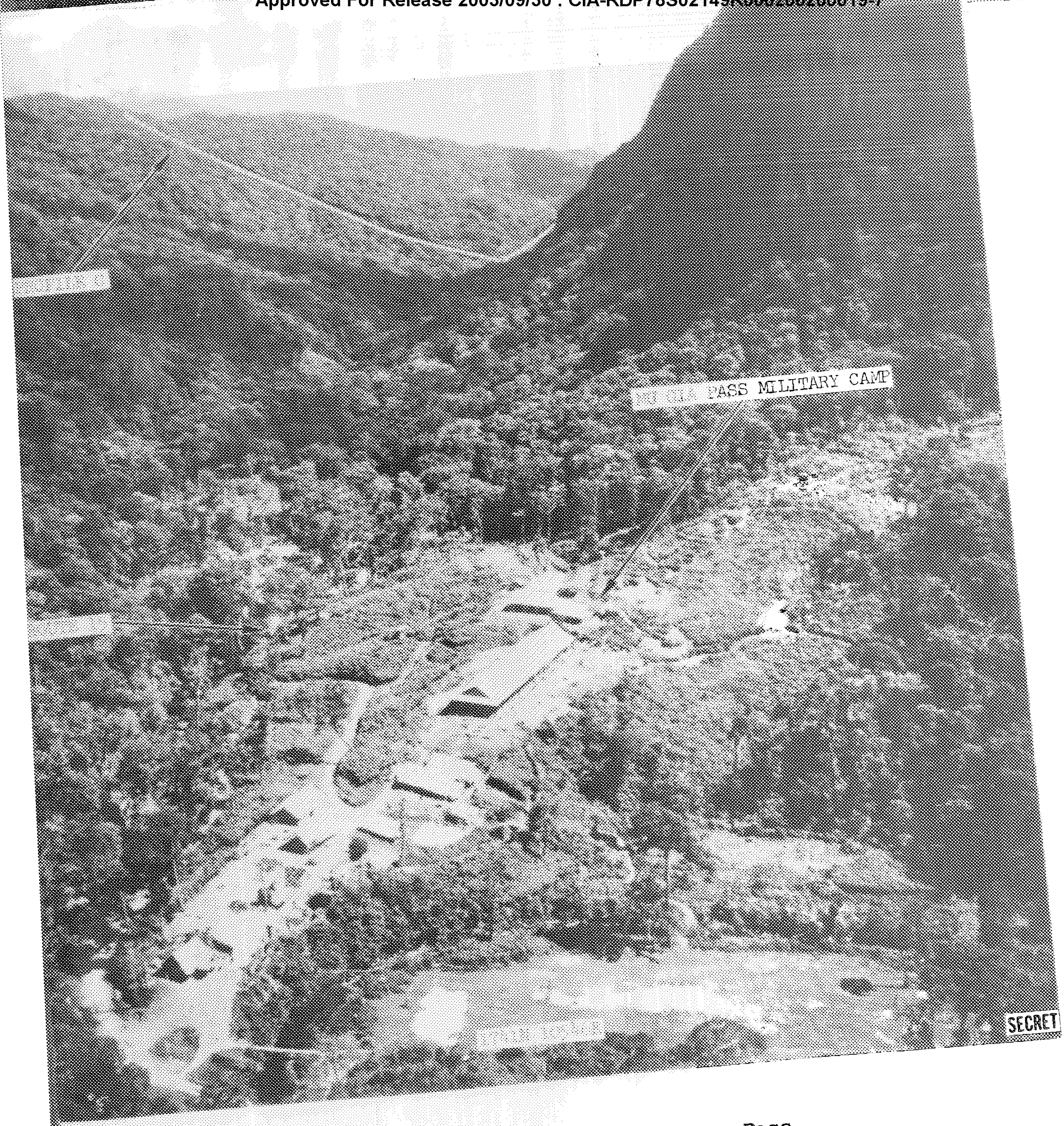


Figure 2. Military Camp at Mu Gia Pass showing road and vegetation.

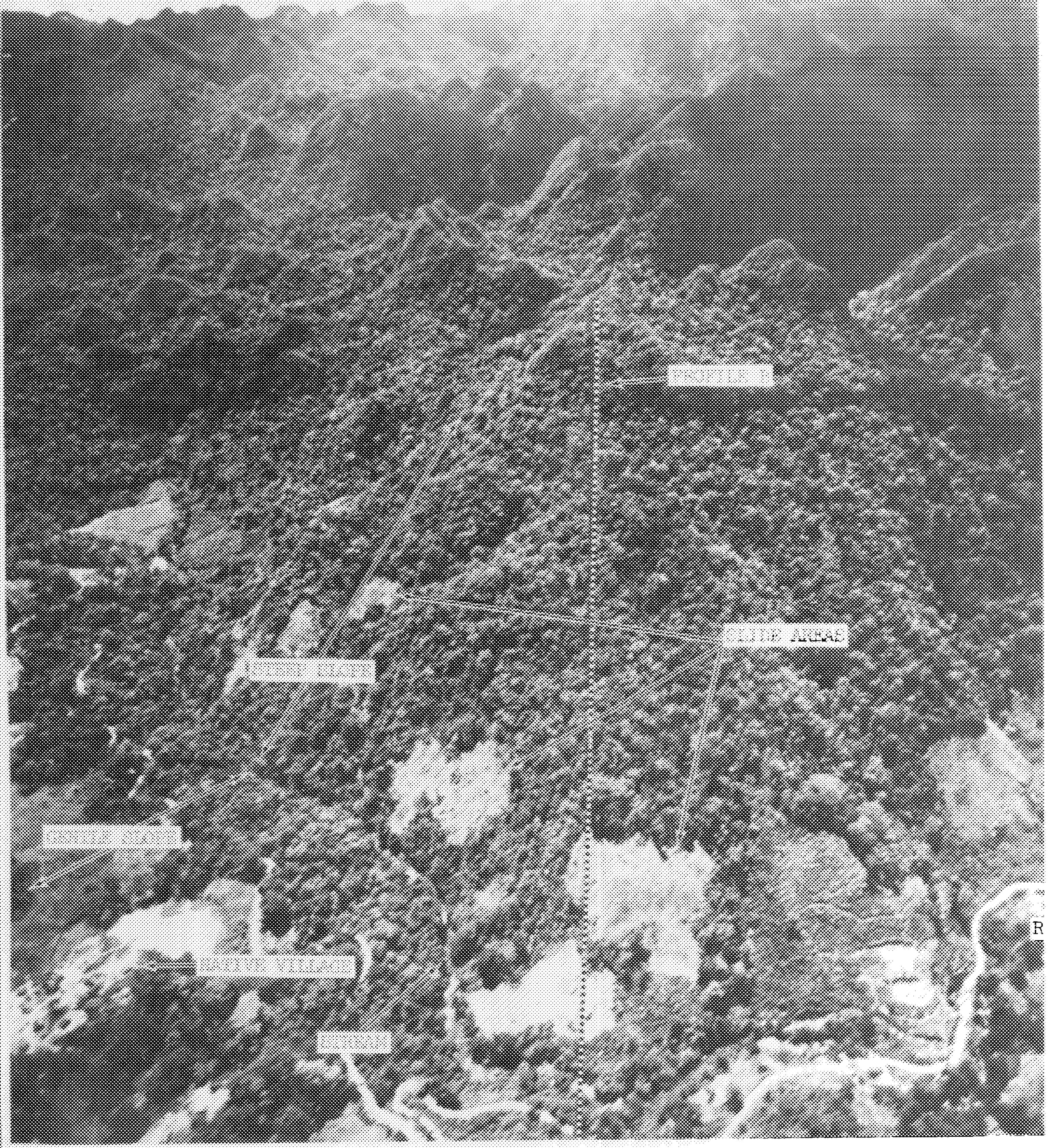

Figure 3. Steep side of Mu Gia Pass showing slides and rough terrain.

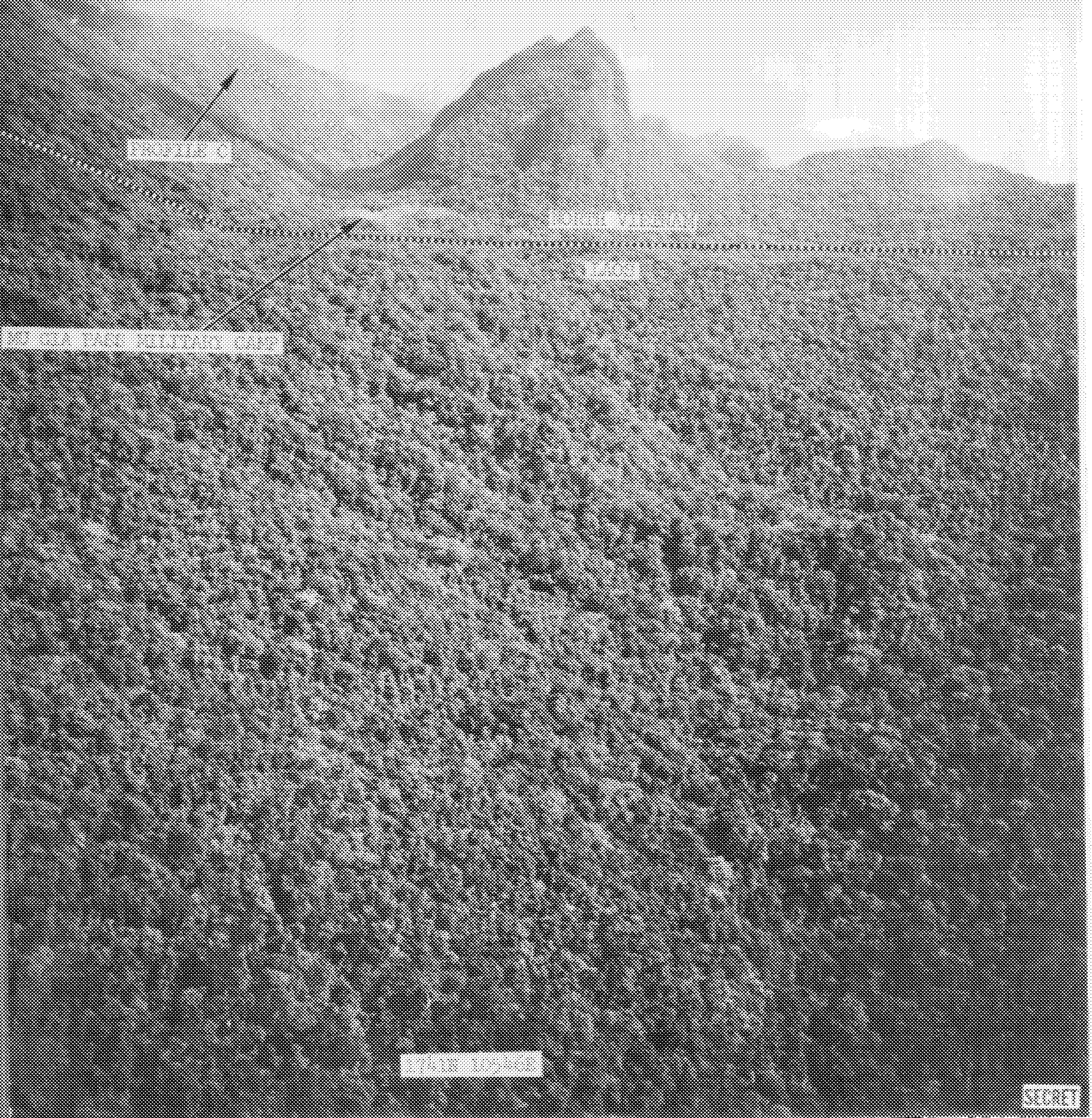


Figure 4. General view of Mu Gia Pass

Figure 5. View of the road north of the Mu gia Pass Proper showing the nature of the terrain and road.

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The most effective ordnance for antipersonnel use is small, on the order of 1 to 3 lbs. Devices of this size will obviously do negligable damage to the road. They might provide severe damage to trucks and personnel on the roads, but the open nature of the roadways will permit clearing of the field with armored vehicles or visual search. The assumed requirements for the denial of area to personnel and for the interdiction of roads are discussed below.

Area Denial:

The concept of area denial needs to be particularized for the purpose of the study. Two measures of the effectiveness for area denial weapons are considered:

a. The expected casualties for a group passing through the area single file without overtly breaching the field.

b. The length of time required to breach the field with negligable casualties.

The length of time required to breach the field is the most significant of the two measures. The analysis assumes that the breaching operations are designed to minimize casualties, although unavoidable losses of reasonable size must be expected.

From an examination of detail maps in the vicinity of the Mu Gia, Kea Neua and Veng Khuch passes, and assuming that the general features and ground cover are similar to those shown in the Mu Gia photographs (Figures 2 through 5), areas have been selected for interdiction to the passage of personnel and are shown in Figures 6, 7 and 8. The widths are chosen so as to provide complete blockage of the passes. The general location of these passes is indicated in Figure 1.

On the basis of area denial alone, the depth of the denied area should be as deep as possible in order to increase the search and mine-sweeping costs. On the other hand, the road acts as a bypass to the area, since it is more readily swept, and can be used to bypass large portions of the area if it is too deep. As a corollary, the road must be interdicted at several points along its route to prevent the portage of materiel around the blockage and the clearing of antipersonnel mines from the road with armored vehicles.

Road Interdiction:

The requirements for effective interdiction of the road are difficult to state. Since it may be possible to pass the

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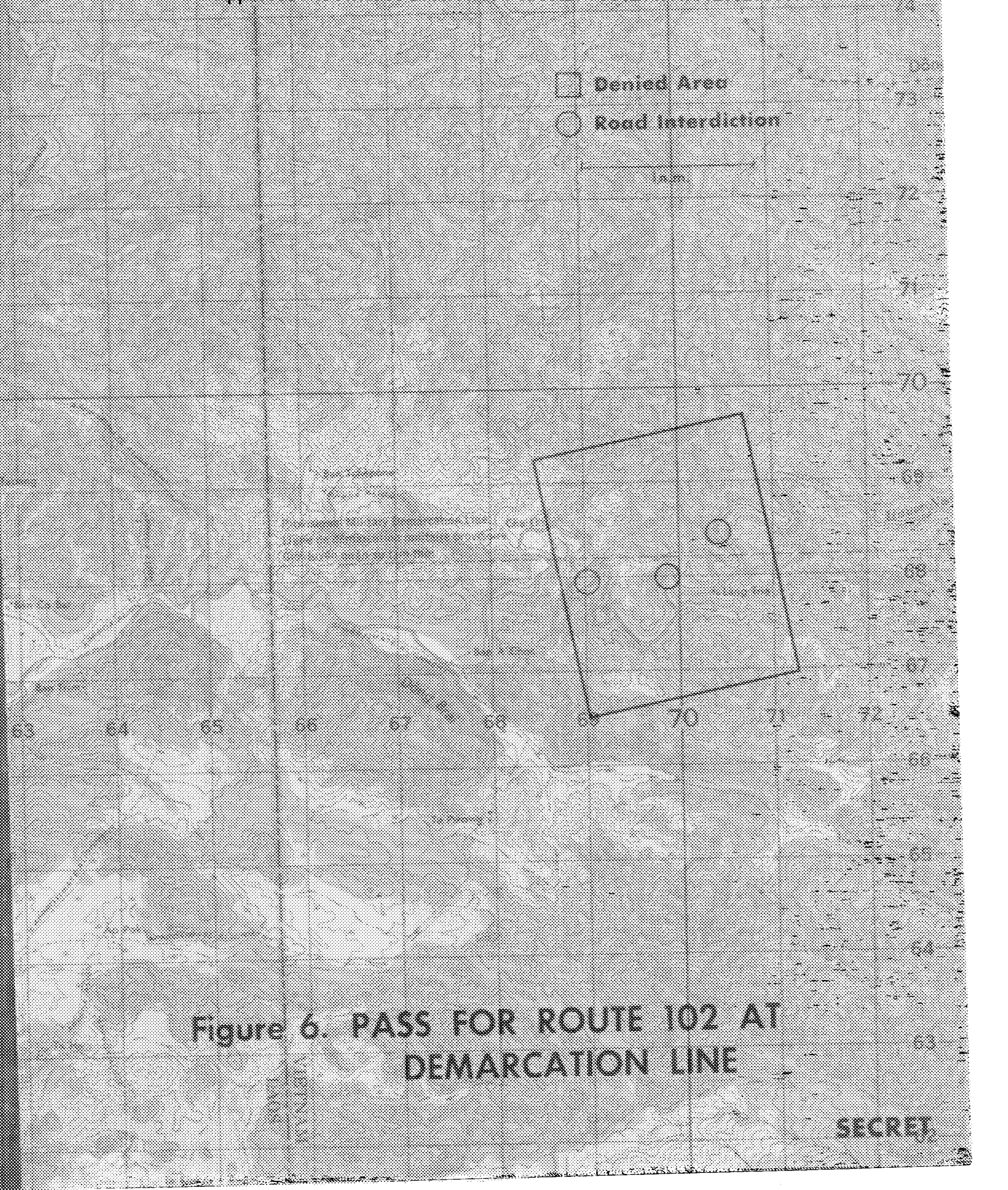


Figure 6. PASS FOR ROUTE 102 AT DEMARCATION LINE

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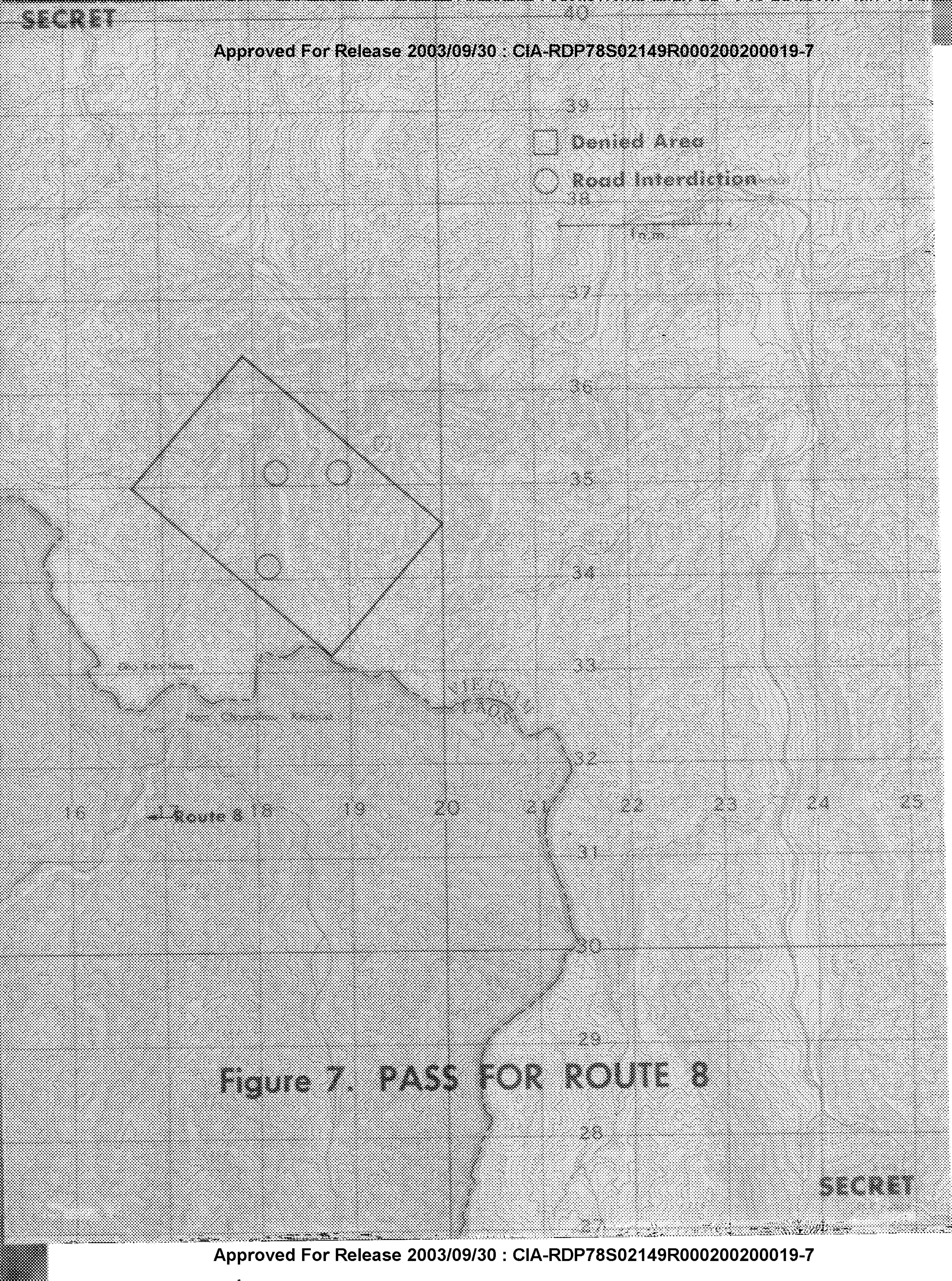


Figure 7. PASS FOR ROUTE 8

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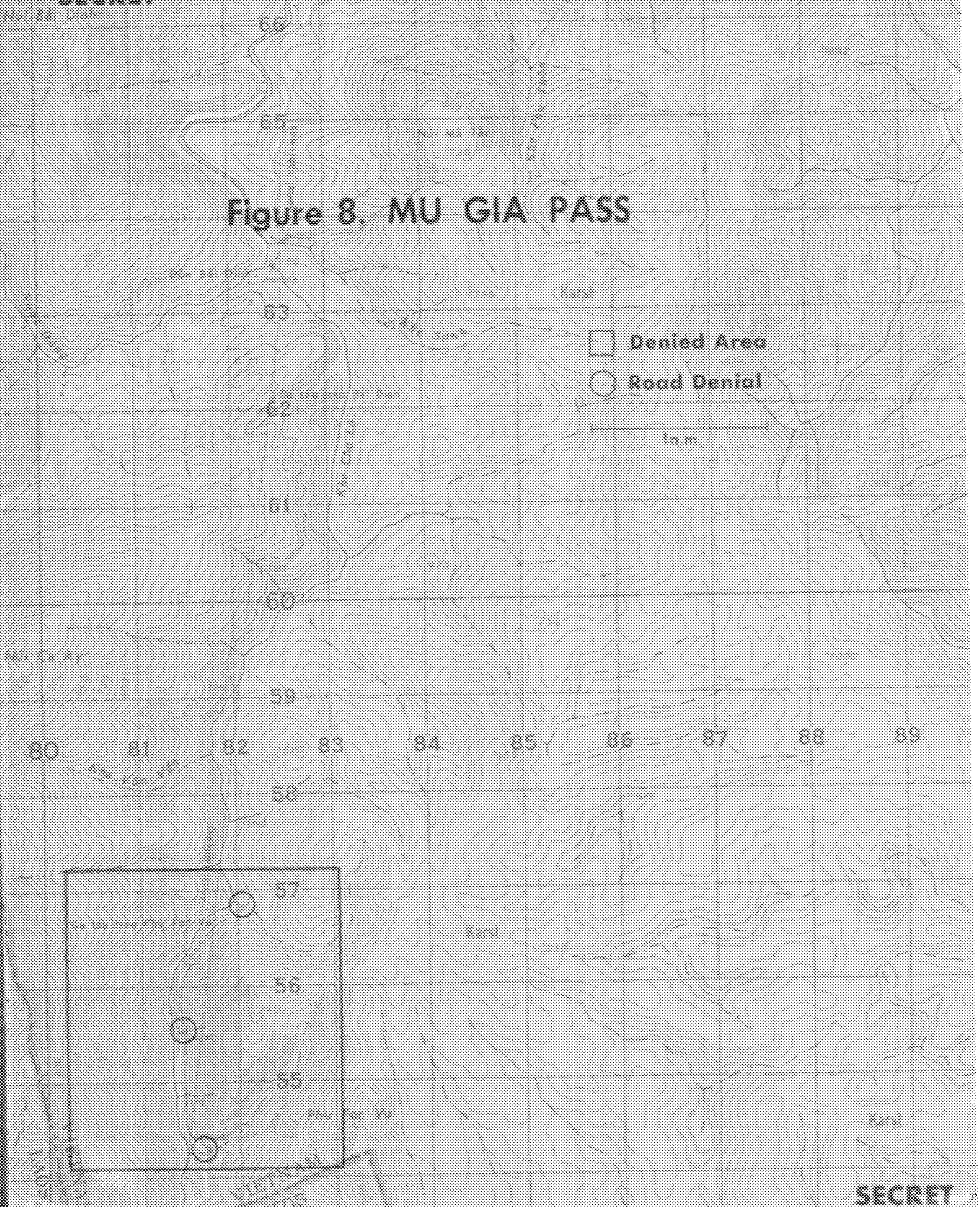


Figure 8. MU GIA PASS

required traffic by opening the road periodically, a system which is effective 90% of the time might be of only marginal value. Two measures of the effectiveness of the road interdiction include:

a. Manhours expended in road repair, and

b. Cost to keep the road continuously breached.

The selection of interdiction points for roads is a dynamic problem, since the natural enemy response is the construction of bypass roads. The point of interdiction must be moved more rapidly than bypasses can be built. When the bypasses to the road form a complete link through the denied area, then there are two roads, each of which will require interdiction with a concomitant increase in ordnance and delivery costs. Figures 6, 7 and 8 show an initial selection of road interdiction points for illustrative purposes.

Navigation:

Navigation adequate for the deployment of the area denial weapons can be provided by Loran C or other electronic navigation aids. These guidance systems have an accuracy of the order of $\frac{1}{2}$ mile, which is small compared to the 1 to 2 mile areas to be interdicted. While Loran C is not now available in the area, it is understood that it is being installed in SEA on a priority basis.

For road interdiction, the accuracy required is much greater. Accuracies under 500 feet are available using map-matching systems with doppler/inertial smoothing. The terrain in the area of the passes should be ideal for the employment of these systems. The problem here is cost, since these devices are provided only on B-47 and B-52 SAC aircraft and are very expensive elaborate systems. Beacons, of course, can be used, even with relatively simple bombing systems, if the offset is not too large. For reliability, however, particularly in an operational environment and during long periods of overcast, the map-matching system would be preferable.

## SELECTION OF ORDNANCE

The basis for the selection of ordnance for area denial and road interdiction is discussed in this section, and considered in greater detail in the Technical Annex. With respect to the basic lethality of the various weapons, the lethality per unit weight of the best available munitions is considered to be close to that ideally achievable. The Trip Wire Mine

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selected as the best for anti-personnel use is only slightly larger than the size found to be optimal in an Air Force study. In the area of fuzing, however, there are many possibilities for improvement which are not currently programmed, particularly for the area denial problem.

In the small bomblet category for anti-personnel use, such as the BLU-26B, the Dragontooth, and Gravel series, currently available fuze devices include instantaneous detonation, random detonation with 90 minutes delay, and pressure sensing. A trip-wire influence and anti-disturbance fuze is well into development, and should be available in quantities by 1967. Plans exist for extending the available random time delay to a period not yet determined for the BLU-26B type device. This is expected to double that current $3.60 cost of this item. The concept of a magnetic fuze sensitive enough to be detonated from the influence field of a rifle is being explored but is considered to be beyond the state-of-the-art. A trip-wire influence fuze with a random delay in deployment of the wires appears to be a desirable type fuze for area denial to impede the sterilization of the mine field.

None of the discussion or literature explored discussed the decoy concept, which is particularly applicable to the Trip Wire Mine since it is so expensive. The use of decoys with mines can increase the time required to sweep a field with only a small additional munitions cost. This factor is considered in greater depth in the Technical Annex.

For road interdiction using only conventional explosive ordnance, heavy weapons are required to damage the road, and random or influence mines are required to make repair difficult and hazardous. Anti-personnel devices could be used to impede the clearing of the large random or influence mines. Presently available heavy ordnance seems to approximate the ideal achievable. The lethal radius of heavy bombs equipped with time delay or influence fuzes is limited to the crater radius, and this, in turn, depends upon the amount of energy released by the explosive selected. This energy release is nearly ideal on a weight basis, unless exotic mixtures are employed, and little growth can be anticipated. Fuzes for this application also exist, both time delay and influence, although cost reduction would be desirable. In view of the very poor historical success with such conventional bombs, this approach is not recommended. Napalm B fire bombs and Trip Wire Mines are recommended to hinder the road damage caused by the high explosive ordnance. A longer burning fire bomb would be desirable.

INTERDICTION OF SELECTED PASSES

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In this section the results of the Technical Annex will be used to estimate costs for the interdiction of the passes illustrated in Figures 6, 7 and 8. The total cost is at least the cost of both the area denial and the road interdiction, since the denial of area implies the interdiction of the road, and vice versa. Table 1 summarizes the area denial costs for the three areas for the requirement that the length of time required to breach the field be equal to 8 hours. Also given are the maximum casualties per penetration if no sweeping were performed. This latter provides an estimate of the casualties suffered if the field is not swept and is a measure of confidence in the adequacy of the field.

These numbers are based upon Table 1.4 of the Technical Annex with some adjustments to account for different assumptions, as defined below. A speed of 3 miles per hour for troops passing through the area when not sweeping the field is assumed as a better figure than the 2 and 4 mile per hour figures given. A trip wire length of 25 feet was used. The Technical Annex was based upon a mine life of 8 hours, instead of a recent value received of 144 hours. Since breaching the mine field at night is not practicable, a field laid at dusk should last for sixteen hours, eliminating 1/3 of the assumed complement of mines required.

A critical assumption in the analysis was the length of time to deactivate a mine. A minute was assumed for both the Dragontooth and Trip Wire Mine. It is felt that 30 seconds and 2 minutes are more appropriate values, respectively, and the costs are adjusted to compensate. The number of casualties per penetration is not regarded as significant, so long as it is large enough to assure that the field is breached. The density of mines is selected such that the sweep rate just equals the replenishment cycle, so that the field is never truly open. On this basis the Dragontooth is more effective than the Trip Wire Mine without decoys. The degree of coverage provided by this cost is marginal, since the assumption is made that sweeping is completed by a single team. Parallel effort by leapfrogging, starting at opposite ends of the trail, or starting in the middle from shelters in the area can greatly reduce the time required to sweep.

The random deployment of the trip wires is a concept which arose too late to be considered in the analysis. This procedure would make the breach of the field practically impossible, since at no time could one have any assurance that the trail was clear. This would require that all parties examine the area through which they were passing with great care, and the movement of men through the area in the best of circumstances would be extremely difficult.

Under the rather rigid models used in the analysis, the denial of area to transversal appears to be very expensive. The reason for this is that simple transversal of an area

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| Best Choice Munition | Time Period | Annual Cost to Maintain Barrier in Millions | Max. Casualties per Penetration |
|---|---|---|---|
| Dragontooth* Mine | Present | 2,200 | 300 |
| Trip Wire Mine used with Decoys in ratio of 1 to 10 | Future | 82 | 20 |

*Figures are almost the same for the Gravel series which is more nearly available.

Table 1. Summary of Costs for Denial of Area to Personnel at the Mu Gia, Kea Neua and Veng Khuch Passes.

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requires only a small time spent in the area and active use of only a very small fraction of the total space. The use of the trip wire mine to deny the use of area appears to be more effective by an order of magnitude than its employment to deny simple transversal. If the life of the mine can be extended appreciably, and this appears possible, the density of mines off the trail and cleared areas would very quickly become so great as to make these areas impenetrable.

The minimal estimate of $1,290 per hour for road interdiction, when multiplied by 9 to cover all three passes at three points each amounts to $\$8.4 \times 10^6$ per month or $\$104. \times 10^6$ per year. The monthly cost per road is roughly comparable to the cost of the Wa-Dong Choke Point interdiction campaign of the Korean War, which met with only slight success. (Reference 1, page E24). In this report, however, more accurate bombing is assumed and the employment of Napalm and area denial weapons to hinder road repair.

The estimated total annual cost to interdict the three passes is therefore on the order of $\$186 \times 10^6$ per year. The cost of our denial is roughly proportional to the total width of the denied areas, and not strongly dependent upon mine life, if the field is regularly swept. The area denial can be almost completely negated by the construction of a covered trench if it were necessary for the enemy to pass through the area.

Additional factors which can affect these numbers are road watching systems and weather problems. If sufficient intelligence exists, it would only be necessary to deny areas and interdict roads which were carrying traffic. If, however, the supplies filter through at a consistent rate as anticipated, this intelligence would be of little value. Weather, of course, would only serve to increase the costs by increasing the dispersion of bombs and mines.

This study used rigid models for the analysis which did not include the side benefits obtained. The restriction of traffic to the narrow cleared trails and the constant and unpredictable hazard of the mine field add plus values to use of the mine field which are not considered. Thus the denial of area to transversal could be considerably more effective than predicated theoretically. For the denial of area use, theoretical and intuitive estimates of effectiveness are more nearly in agreement, and this application of the trip wire mine appears to have the greatest promise.

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# TECHNICAL ANNEX

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## INTRODUCTION

This report presents the results of a brief study of the long-term area denial and road interdiction problems for the case in which air superiority is maintained, and the areas in question are under enemy control. In particular, cost effectiveness analyses of the use of air-delivered conventional bombs, time delay bombs, and mines for this purpose were conducted.

Due to the limited time available for this study, it was not possible to inquire deeply into all of the costs associated with the air delivery of munitions or all of the factors which completely describe effectiveness. For purposes of this study, cost is defined in terms of the unit cost of each munition. The effectiveness is defined in terms of casualties and in terms of the burden imposed on the enemy to clear a path through the minefield. It is recognized that delivery costs must be accounted for in a complete analysis of problems of this type. In this study, however, comparisons are made using similar aircraft in such a way that the delivery cost is very nearly the same for the cases considered and is, to the extent possible, minimized.

As noted earlier, a second measure of effectiveness has been employed in this study, since it is believed that the enemy can and will sweep minefields and need not therefore accept casualties. It is recognized that a quantitative treatment of the time delay associated with clearing a minefield is not strictly possible. However, reasonable comparisons can be made on this basis, and realistic appraisal of the use of mines for the purpose of area denial can be obtained in this way.

In Section I, the area denial problem is discussed and the study results obtained are presented. Two distinct situations are considered; in the first it is assumed that the enemy will tolerate casualties. The results presented give the expected fraction of casualties in terms of the rate of personnel movement, the geometry of the area, the types of munition, and the expenditure rate. In the second situation, it is assumed that in response to a small number of casualties, the enemy will clear a path through the barrier and then continue his movement. Here the expenditure rate is given in terms of the previously mentioned parameters and the estimated rate at which the field can be cleared. For this case the concept of introducing decoy mines and modified trip wire mines was investigated.

The case of random troop movements through the mined area is not considered separately; since it is expected such penetration will cease once the mined area is entered. In this way the enemy will minimize both casualties and the burden associated with breaching.

Section II deals with the interdiction of roads. In this case, it is assumed that the road is broken with antimateriel bombs and that the enemy is harassed with mines and time delay bombs during repair attempts. Both casualties and time are considered as meaningful effectiveness measures in this case. As earlier the rate of expenditure is related to effectiveness in terms of the pertinent factors.

SECTION I

AREA DENIAL

## INTRODUCTION

In this section the use of aerially emplaced minefields as a means of area denial is examined from a cost-effectiveness point of view. This was done for the various mines described in Table 1.1 and for certain modifications of these, which were suggested by the results. The problem of area denial for extended periods is complicated since breaching of mine barriers can be readily accomplished given sufficient time. [1/] Under these conditions, the most realistic measure of the effectiveness of the minefield can no longer be taken to be casualties. In this analysis effectiveness is measured in two ways depending on the situation; by casualties and by the burden imposed on the enemy to breach the field. The specifics of the various factors considered and the results obtained are presented.

## ENEMY RESPONSE

The principal difficulty of this problem hinges on the nature of the response of the enemy to a minefield, which it is thought will be readily discovered either in consequence of casualties or by direct

[1/] Institute for Defense Analyses, Weapons Systems Evaluation Division, Aerially Emplaced Antipersonnel Mines (U), WSEG Report 95, March 1966, SECRET.

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TABLE 1.1

MUNITIONS CONSIDERED

| Name (Mil. Designation) | Weight | Size and Shape | Unit Cost, dollars | Mean Area of Effectiveness | Active Life | Description |
|---|---|---|---|---|---|---|
| Gravel AP Mine (XM-27) | 3 oz | 3-in. wedge | 1.70 | See footnote 1 | 3-12 hr depending on temperature | Actuated by direct contact |
| Dragontooth AP Mine | 1 oz | $1\frac{1}{2}$-in. wedge | 1.20 | See footnote 1 | 7-18 hr depending on temperature | Actuated by direct contact |
| GP Bomb (Mk81) | 260 lb | 76.5-in. long 9.0-in. diameter | 523.00 2/ | 450 $ft^3$ 3/ | 20 min-35 hr in 35 increments | Used with time fuze 4/ as a mine |
| Trip Wire | 14 oz | $2\frac{1}{4}$-in. sphere with 8-25-ft actuating wires | 27.00 | See footnote 5 | 8 hr now with batt. 72 hr proj. | Actuated by 30-lb tension in wires or by moving |

1/ Effective area described by footprint area of man plus a correction for the size of the device.

2/ Estimated cost of munition and fuze.

3/ Approximate crater size for Mk 81 in loose soil. This is assumed to define the effects area. It is to be noted here that this combination is taken for illustrative purposes only. In fact it is expected that the munition will break up upon penetration of the soil and hence cannot be used in this way.

4/ Fuze FMU-35/B. 25X1

5/ Casualty producing effects extend to limits of area described by terminations of trip wire.

observation.[2/] On discovery, the enemy can be expected to respond in a variety of possible ways, each of which influences the value of the field. The distinct possible responses are seen to be:

a. Penetrate the minefield and accept the resulting casualties;

b. Force the field to be penetrated by prisoners, civilians, or livestock until the trail is clear;

c. Locate the mines along the trail and by one means or another deactivate or otherwise render them ineffective.

If it is believed that minefields will be periodically seeded, he can, in addition:

d. Abandon the area in question and penetrate elsewhere;

e. Construct a slit trench, perhaps covered, through the mined area.

The specific response will, of course, depend on the amount of information available to the enemy and the requirements of the particular mission. In the case at hand, the situation of interest is strategic in nature so that time is generally not critical. It is therefore thought that the response of accepting casualties will not occur. Nevertheless, this option is considered in this study.

The requirements of this study preclude the option of avoiding the mined area. Thus, this response was not examined in this study. The last response could be employed, particularly if it is known that the minefield is continually being replaced. This option is considered in this study.

EFFECTIVENESS

The remarks concerning possible enemy responses to minefields make it clear that casualties is not in fact the important effectiveness measure of mine barriers. It is believed that some measure of the burden imposed on the enemy to breach the minefield is a more appropriate measure. In this study the time required to clear a narrow trail of

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2/ Ibid.



[redacted]

mines is taken to be the effectiveness measure for the cases examined. For the case in which a trench is constructed, the burden on the enemy is simply the associated man-hours. In this case, unless the trench is detected, the burden occurs once. Thus, area denial is no longer possible without finding and neutralizing the trench.

## DELIVERY COST

The cost associated with the delivery of the various mines is quite variable, depending on the vehicle, the mission, and attrition of the delivery system. In Table 1.2 estimates of the operational costs and the attrition costs are given. These values were obtained from the Air Force Armament Laboratory.[3/] As can be seen, the A1E aircraft in terms of effective payload per sortie hour is by a wide margin the vehicle of choice. To the extent permitted by weapon compatibility, this vehicle will be taken to be the delivery vehicle. Except for the case of the use of napalm which is considered in the section on road interdiction, the delivery costs can be reasonably neglected for purposes of this analysis.

## METEOROLOGICAL CONDITIONS

Under poor weather conditions, the location of the target area will present some considerable difficulty. Existing inertial navigation systems suitable for aircraft installation do not meet the requirements here; that is, to locate the target center to within about one-half to one mile. Current capabilities of U.S. Navy patrol aircraft provide a 3 percent error on straight courses in both range and bearing. Thus, at 100 miles the target center could only be located to within a 6x6-mile area. LORAN systems are inherently capable of meeting the requirements here. However, adequate coverage would be required over the area of interest. Such systems are capable of obtaining fixes to within less than one-half mile. This estimate is based on present coverage and existing installations in certain naval vessels. It is doubted that the required coverage (location of LORAN stations) is available for the area of interest in this study. An alternative technique would consist of dropping radio beacons in the area in question. This appears to be a reasonable approach; however, the difficulties of implementation have not been examined.

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3/ Air Force Armament Laboratory, Weapons Division, Eglin Air Force Base, Florida.

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TABLE 1.2

AIRCRAFT OPERATING COSTS IN WAR

| Aircraft | A1E | F100 | F4C | F105 |
|---|---|---|---|---|
| Estimated War Cost/ Sortie (dollars) | 594 | 824 | 5,190 | 6,900 |
| Average Hours/Sortie | 1.8 | 1.3 | 2.5 | 2.5 |
| Attrition Cost/ Sortie (dollars) | 250 | 960 | 9,230 | 19,100 |
| Total Cost/Sortie (dollars) | 844 | 1,784 | 14,420 | 26,000 |
| Total Cost/Hour (dollars/hour) | 469 | 1,370 | 5,770 | 10,400 |

The problem of altitude determination and the location of obstacles, such as mountains, can be handled with existing radar systems.

MUNITIONS

Existing and projected munitions were examined for application to the long-term area denial problem. Those which were selected for examination are described in Table 1.1.

In consequence of the results obtained for specific situations, the concept of introducing "decoy" mines in the minefield and of introducing a delay fuze in the trip wire mine was examined.

SITUATIONS EXAMINED

For purposes of this study, it was supposed that an enemy trail of width 3 ft has been located to within an area of the dimensions given in Table 1.3.

TABLE 1.3

DIMENSIONS OF AREA TO BE DENIED

| Depth, ft | Width, ft |
|---|---|
| 5,000 | 3,000 |

Along the trail, it was assumed that personnel would move at speeds of 2 and 4 miles/hr and that the number of personnel using the trail would be either 20/hr or 100/hr. The case in which personnel move at random through the mined area was not considered since it is believed that the enemy would not behave this way in a minefield.

NATURE OF MINEFIELD

For each type of mine considered, it was assumed that a minefield would be created with the mines being located uniformly at random over the entire area. Strictly speaking, this will not occur due to the patterns obtainable with available delivery techniques. However, the errors introduced by making this assumption are not important insofar as this study is concerned.

Since long-term area denial is required, continued reseeding of the minefield is assumed. Based on the life of the various mines considered, it was assumed that reseeding occurs at time intervals of 8 hr, which is the approximate life of the mines being considered.

## TREATMENT OF COST

The delivery cost was treated as described earlier. The munition costs take into account disperser costs and were obtained from other reports.[4,5] These are given in Table 1.1 along with other characteristics.

## FORMULA

In this study both casualties and the time delay associated with the clearing of a minefield are taken to be the measures of effectiveness for the barrier. The appropriate relationships follow.

$$E_f \text{ (expected fraction of casualties)} = \frac{f}{W} \cdot \frac{C}{KC_i}$$

$$\tau_d \text{ (time lost in clearing the trail)} = D\left[\frac{1}{V_2} - \frac{1}{V_1}\right] + \frac{f\tau C}{WC_i}$$

where f is a length which relates to the particular muniton. The remaining parameters are:

- D : depth of the barrier in feet
- W : width of the barrier in feet
- $V_1$ : the speed at which the trail through the minefield will be searched in mph
- $V_2$ : normal speed of troop movement in mph
- K : the rate of troop movement in personnel per hour
- $\tau$ : the time in hours required to dispose of one mine

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4/ Institute for Defense Analyses, WSEG Report 95, op.cit.

5/ U.S. Air Force, Nonnuclear Consumables, Weapons Handbook, Volume IV, for Fiscal Years 1967–1971, 1 October 1965, SECRET [redacted]

$C_i$ : unit cost of the mine in dollars

$C$ : total cost in dollars

$\dot{C}$ : expenditure rate in dollars per hour.

The factor f is as follows for two of the three types of mine considered.

$$f = \frac{4\,\ell_w}{\pi} \quad \text{(trip wire mine)}$$

$$f = W_p \quad \text{(footprint mine)}.$$

The formulation for the time delay mine is somewhat different and is as follows

$$E_f = \frac{8(MAE)}{\pi^2 V_1 W} \cdot \frac{\dot{C}}{C_i} \ .$$

The use of the time delay mine as a means of imposing a time burden on the enemy was not considered for the reasons noted in Table 1.3 A. The additional parameters are

$W_p$ : width of the trail in feet

$\ell_w$ : the effective length of the trip wire in feet

MAE : mean area of effectiveness for the time delay mine.

In the case of casualties, it is assumed that the field is reseeded periodically with the time between reseeding taken to be the life of the mine.

The formulas are in each instance of the form

$$E_f = a\,\dot{C}$$

and

$$\tau_d = (b + d\,C).$$

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[redacted]

TABLE 1.3 A

COST-EFFECTIVENESS TABLE FOR MUNITIONS CONSIDERED

| Situation[1] | | | Casualties / Unit Cost, no/dollar | | | | Time Burden/Unit Cost,[2] hr/dollar | | | | Fixed[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Troop Rate | Troop Speed | Trip Wire Length | Trip Wire | Gravel | Dragon-tooth | Time Delay | Trip Wire | Gravel | Dragon-tooth | Time Delay[3] | Time Burden |
| 100/hr | 2mph | 12.5ft | $1.97x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.022x10^{-4}$ | $3.28x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .473hr |
| 100/hr | 2mph | 25 ft | $3.93x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.022x10^{-4}$ | $6.56x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .473hr |
| 100/hr | 4mph | 12.5ft | $1.97x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.011x10^{-4}$ | $3.28x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .71 hr |
| 100/hr | 4mph | 25 ft | $3.93x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.011x10^{-4}$ | $6.56x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .71 hr |
| 20/hr | 2mph | 12.5ft | $1.97x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.0044x10^{-4}$ | $3.28x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .473hr |
| 20/hr | 2mph | 25 ft | $3.93x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.0044x10^{-4}$ | $6.56x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .473hr |
| 20/hr | 4mph | 12.5ft | $1.97x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.0022x10^{-4}$ | $3.28x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .71 hr |
| 20/hr | 4mph | 25 ft | $3.93x10^{-4}$ | $5.88x10^{-4}$ | $8.34x10^{-4}$ | $.0022x10^{-4}$ | $6.56x10^{-6}$ | $9.8x10^{-6}$ | $13.9x10^{-6}$ | — | .71 hr |

1/ A barrier field 5000 ft deep and 3000 ft wide is considered. It is assumed to be reseeded at 8-hr intervals.

2/ It is assumed that 1 min is required to clear a single mine.

3/ Since time delay mines cannot be cleared effectively, they could, in fact, have a negative effect on time burden per unit cost—they would encourage the enemy to traverse the field as quickly as possible.

4/ The fixed time burden associated with a minefield is the time associated with the slow down of the enemydue to the existance of the barrier.

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RESULTS

The parameters a, b, and d are measures of the cost-effectiveness performance of the munitions, and their values are given in Table 1.3Bfor the cases considered. The case of decoys requires a different treatment since casualties occur only from live mines, but the time burden depends on the total number. Let $C_{ia}$ be the average cost per item and R the ratio of live mines to decoys. The value of $E_f$ for the same minefield is then given by

$$E_f = \frac{a}{R+1} \dot{C}$$

and $C_{ia}$ is used as the unit cost for both casualties and time delay. In Table 1.3B,the values presented take this matter into account.

The calculations made using decoys were based on an estimated cost of $.27/decoy and a ratio of decoys to live mines of 10. The decoy is assumed to be a length of wire of the same kind as used in the trip wire mine and the same effective length. It is assumed that it could be made to lie across the trail and be indistinguishable from the trip wire associated with a trip wire mine.

Comparisons between the alternative munitions can be obtained directly from this table. For presently available mines, noting that decoys are not available, the dragontooth mine is clearly the weapon of choice. By introducing decoys with the trip wire mine, it becomes the weapon of choice insofar as the time delay burden is concerned, but the dragontooth remains the most effective insofar as casualties are concerned.

In Table 1.4 the annual cost and casualties associated with keeping the time burden such that the enemy is continuously engaged in clearing the trail or must accept casualties are presented for the munitions of choice and the situations considered. To obtain the associated costs for other areas, the values in this table are multiplied by W/3000, where W is the width of the area in question. It is assumed here that the minefield is reseeded at 8-hr intervals which is taken to be the life of the mines.

By increasing the life of the mine, the cost to maintain the barrier decreases as do the expected casualties.

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TABLE 1.3 B

COST-EFFECTIVENESS TABLE FOR MUNITIONS CONSIDERED

Trip Wire AP Mine, Decoys Considered

| Effective Trip Wire Length | Decoy/Live Mine Ratio | Clearing Time/Mine | Casualties/ Unit Cost | Time[1/] Burden/ Unit Cost |
|---|---|---|---|---|
| 12.5ft | 0 | 1 min/mine | $1.97 x 10^{-4}$ | $3.28 x 10^{-6}$ |
| 25 ft | 0 | 1 min/mine | $3.93 x 10^{-4}$ | $6.56 x 10^{-6}$ |
| 12.5ft | 10 | 1 min/mine | $1.78 x 10^{-4}$ | $32.8 x 10^{-6}$ |
| 25 ft | 10 | 1 min/mine | $3.57 x 10^{-4}$ | $65.6 x 10^{-6}$ |
| 12.5ft | 0 | 4 min/mine | $1.97 x 10^{-4}$ | $13.1 x 10^{-6}$ |
| 25 ft | 0 | 4 min/mine | $3.93 x 10^{-4}$ | $26.2 x 10^{-6}$ |
| 12.5ft | 10 | 4 min/mine | $1.78 x 10^{-4}$ | $131 x 10^{-6}$ |
| 25 ft | 10 | 4 min/mine | $3.57 x 10^{-4}$ | $262 x 10^{-6}$ |

[1/] Plus fixed time burden of .473 hr for slowdown from 2 to 1 mph, or .71 hr for slowdown from 4 to 1 mph.

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To explore the situation further, a time delay fuze is introduced in the trip wire mine which serves to increase the time delay burden and unfortunately decreases the casualties. An average 4-min delay fuze was considered with detonation occurring at random in 0 to 8 min. To account for this in the casualties, it was assumed that if a man tripped a mine he would run to get out of range. On the basis of a running speed of 100 yd in 30 sec, the average probability of not being killed is for a weapon radius of 25 ft, approximately $1.3 \times 10^{-3}$.

CONCLUSIONS

The results presented in Table 1.4 are the best found in this examination and are therefore the basis of the conclusions of this study. In each specific case, the annual expenditure cannot be decreased since in so doing the minefield would be inactive for certain periods of the day which would allow penetration by the enemy with no casualties.

For presently available munitions, the dragontooth is the best choice for area denial applications. In the future, the use of trip wire mines with decoys appears a better choice. The further introduction of a time delay fuze offers an advantage in the sense that costs are reduced. However, casualties are similarly reduced. Depending on the importance of casualties to the enemy, a mix of trip wire mines with decoys, with and without time delay fuzes, is recommended. Since there is no basis to determine the relative value of casualties, it is not possible to make a specific recommendation.

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TABLE 1.4

TABLE OF ANNUAL COST AND ASSOCIATED CASUALTIES TO MAINTAIN A CONTINUOUS BARRIER

| Munition | Situation | | Annual Cost to Maintain Barrier, millions of dollars | Maximum Annual Casualties* |
|---|---|---|---|---|
| Dragontooth | All Considered | | $365.\times10^6$ | 328,500 |
| | $\ell$ w (ft) | v(mph) | | |
| Trip Wire with Decoys | 12.5 | 2 | $167\times10^6$ | 139,500 |
| | 25 | 2 | $84\times10^6$ | 70,000 |
| | 12.5 | 4 | $163\times10^6$ | 119,000 |
| | 25 | 4 | $81\times10^6$ | 59,100 |
| Trip Wire with Decoys and Delayed Fuze | 12.5 | 2 | $42\times10^6$ | 45 |
| | 25 | 2 | $21\times10^6$ | 23 |
| | 12.5 | 4 | $41\times10^6$ | 39 |
| | 25 | 4 | $20\times10^6$ | 19 |

* Maximum casualties is defined on the assumption that each mine on the path produces a casualty. If the number of personnel using the path is not larger than this, the number of casualties will be proportionately smaller

## SECTION II

## ROAD INTERDICTION

### INTRODUCTION

In this section the problem of closing a road for extended periods to all enemy traffic is examined. Following the statement of the problem, it is assumed that the traffic flow on the road is small compared to the capacity and that time is not an important element to the enemy. Under these conditions road interdiction is ineffective unless the road is closed to all traffic 24 hr/day for an extended period. This is the basis of the results described in this section.

### A METHOD OF INTERDICTION

There is little question that a road can be effectively interdicted for brief periods, and similarly it has been shown that roads can be rapidly and effectively repaired in a matter of hours. The question is, how to close the road without bombing and strafing on a relatively continual basis. Various possibilities using bombs, land mines, antipersonnel mines, time delay bombs, and napalm were considered for application to this problem. These examinations yielded the following concept for examination. Specifically, it is proposed to create a break in the road with conventional bombs and then to prevent the repair of the road with the use of napalm. The sequence of events is as follows:

a. Create a hole in the road;

b. Allow road repair to commence;

c. Neglect the road as long as no repair attempt is made and for periods which are somewhat shorter than the minimum estimated repair time;

d. At night, use napalm so that the hole cannot be repaired before daybreak;

e. Start the process over by creating another hole in the road.

NAPALM

In this problem it is necessary to account for the delivery costs due to the low cost of napalm bombs. To this end the A1E aircraft is used due to its low comparative operating cost of $469/hr, as shown in Table 1.1 of Section I. Using the large BLU-27/B napalm-B filled fire bomb and the A1E aircraft, it is estimated that one aircraft can prevent the enemy from repairing the road at night for approximately 35 min at a total cost, including delivery, of $1412.00. To continue the process through the night for 10 hr would require a total expenditure of $28,240.00. The annual expenditure rate would be $10.3 million/year to close the road during the night.

It would of course be necessary to do this continuously during the night so that the fire could be used as the aim point. This would also serve to reduce the difficulties associated with poor weather conditions.

BREAKING THE ROAD

During the day a hole would be put in the road and repair would be prevented, again using napalm. Recognizing that continual attention around the clock is to be avoided, the bomb which leads to the best cost-effectiveness solution for a hole in the road should be selected where the burden on the enemy is measured in terms of the total effort required to repair the road. This problem was examined for the bombs given in Table 2.1. The data presented, which includes

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bombing errors, were obtained from the Institute for Defense Analyses.[1] Other munitions were examined and final selection made from those given in Table 2.1.

TABLE 2.1

TABLE OF MUNITIONS EXAMINED

| Bomb Type | Nomenclature | Weight, lb | Cost, $ | Aiming Error (CEP), ft |
|---|---|---|---|---|
| GP Retarded | Mk 81 | 250 | 335 | 130 |
| GP Retarded | Mk 82 | 500 | 420 | 130 |
| GP Retarded | M 117 | 750 | 650 | 130 |
| Air to Ground | AGM 12/B | 500 | 4,500 | 30 |
| Missile | AGM 12/C | 1000 | 8,170 | 30 |
| Missile | AGM 62/A | 1000 | 32,000 | 15 |
| Aerial Land Mine | MLU-10/B | 750 | 1,460 | 30 |
| Antimateriel Penetration | BLU-14/B | 660 | 1,021 | 30 |

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Based on the aiming errors and costs given in Table 2.1 and crater sizes [redacted] the average cost to break the road was calculated in the conventional manner. The results of these calculations are given in Table 2.2.

TABLE 2.2

AVERAGE COST TO BREAK A 10-ft WIDE ROAD

| Munition | Required Bomb Load | Average Cost, $ |
|---|---|---|
| Mk 81 | 21 | 7,000 |
| Mk 82 | 12 | 5,200 |
| M 117 | 11 | 7,200 |
| AGM 12/B | 5 | 21,600 |
| AGM 12/C | 3 | 23,700 |
| AGM 62/A | 2 | 54,000 |
| MLU-10/B | 5 | 7,000 |
| BLU-14/B | 5 | 4,900 |

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1/ Institute for Defense Analyses, Weapons Systems Evaluation Division, Aerially Emplaced Antipersonnel Mines (U), WSEG Rpt. 95, March '66, SECRET

[redacted]

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[redacted]

The burden on the enemy is strictly proportional to the volume of the crater which depends on a variety of factors. For typical unpaved road conditions, it can be reasonably assumed that the depth of the crater formed by an aerially delivered munition will be about one-third the crater diameter. The crater volume is approximately conical so that

$$V = \frac{\pi d^3}{48} \; .$$

If the volume is expressed in cubic yards and the diameter in feet,

$$V_{CY} = \frac{\pi d^3}{1296} \; .$$

The productivity of men and machines in filling a crater likewise depends on many factors; such as, the availability of fill and soil hardness. A small bulldozer (e.g., the D6) can be assumed to have a productivity of about 25 cu yd/hr in a typical crater-filling operation. Men with shovels can be assumed to fill at about $\frac{1}{2}$ cu yd/hr, each. An engineer squad could fill a crater at about 5 cu yd/hr.

Using these results and the costs associated with breaking the road, the effectiveness of the bombing attack was rated in terms of the time required to fill the hole and the cost to create the hole. Of all the munitions considered, the Mk 82 and BLU-14/B demonstrate the best cost-effectiveness performance. The results of these calculations are shown in Table 2.3

TABLE 2.3

THE COST OF BREAKING THE ROAD AND THE TIME TO REPAIR IT

| Bomb | Crater Diameter, ft | Repair Time, hr Man | Repair Time, hr Bulldozer | Average Cost to Create Hole, $ |
|---|---|---|---|---|
| Mk 82 | 32 | 16.7 | 3.1 | 5200 |
| BLU-14/B | 24 | 6.5 | 1.3 | 4900 |

The munition of choice is clearly the Mk 82.

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INTERDICTION COST

The selection of the use of bombs in conjunction with napalm depends heavily on the availability of heavy equipment. In any case, the cost of breaking the road and maintaining a break with bombs is for the Mk 82, including the cost of the aircraft for 2 hr is approximately \$2618/hr if heaving equipment is available and \$1256/hr if the road is repaired manually. The hourly rate for napalm on the same basis is \$2824/hr. Although the bombing can be accomplished at a somewhat lower cost than the napalm, it is not expected that sufficient accuracy can be obtained at night. On this basis the optimum solution is to break the road at 3-hr intervals during the day and to prevent the repair of the last hole during the night with napalm. Using 14 hr of bombing during the day and 10 hr of napalm bombing at night, the total annual expenditure to interdict the road is \$16.7 million if the repair of the road is accomplished manually and \$23.6 million if the road is repaired using heavy equipment.

The possibility of using napalm alone is rejected since it is expected that vehicles could dash through the burning area. The hole in the road would prevent this action. It can similarly be expected that the enemy will respond to this situation with either ground fire or aerial attack. The consequences of this response have not been examined in this study but could substantially increase the costs associated with interdicting a road.